SMR systems are typically configured using a single high elevation tower, high-power station that provides communications coverage throughout a limited geographic local service area. Users can communicate with other members of their talk groups, and in some cases, can access the public switched telephone network (PSTN) through limited interconnection capabilities. Some SMR providers offer limited data capabilities within their local service area.

Enhanced Specialized Mobile Radio

Enhanced SMR services, also known as ESMR or wide-area SMR services, are digital telecommunications services that offer customers an integrated package of wireless services, including not only dispatch, but also interconnected mobile telephone (cellular), alpha-numeric paging, and data capabilities. The ESMR system is designed and constructed similarly to a cellular system in that it employs a multiple low-power, low-tower configuration that enables telephone call "hand-off" as a user moves through the ESMR network coverage.

Specialized Mobile Radio (SMR) and Enhanced Specialized Mobile Radio (ESMR) systems currently have limited use by some public safety agencies. Some SMR and ESMR providers have responded to major events, such as the Oklahoma City bombing and the Northridge (CA) earthquake. They have installed new radio sites to increase capacity and provided mobile radio units to public service agencies such as the American Red Cross and to some public safety agencies. In general, these services were not used by "first responder" units, but were a valuable resource for public service units, such as the Red Cross, which were providing support and assistance.

Some public safety agencies have entered into cooperative agreements with local SMR/ESMR providers. Through these agreements, the public safety agency may provide one or more radio channels (typically in the 800 MHz band) which is added to the SMR system. In some cases, availability of the "public safety" channel(s) is partitioned[4], while still retaining access to the remaining channels in the SMR/ESMR system. In this way, the public safety user has access to the full capabilities of the system, plus exclusive access to the partitioned channels.

SMR and ESMR systems suffer many of the interoperability problems faced by public safety systems. First, different systems operate with equipment supplied by different manufacturers. Oftentimes, equipment from one SMR/ESMR system may not have the proper signalling and operational protocols programmed to operate within a system provided a another manufacturer. Even if the equipment were technically compatible, many SMR/ESMR systems prohibit "roaming"[5] between systems for economic reasons. Second, SMR/ESMR systems are designed to provide optimal communications to a defined customer base within a specified area of operation. Thus, the amount of service which might be available and the

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4 A "partitioned" channel is typically reserved for exclusive use of the public safety agency, while other users are "blocked" from access to the channel.

5 "Roaming" is simply defined as the ability of a subscriber unit to operate in other systems when outside the coverage area of its home system.

area within which that service is available was defined by the needs of the customer base and not upon the needs of the public safety users. Third, few public safety agencies use SMR/ESMR services on a routine basis, therefore, they are not equipped to utilize the services in an emergency. Thus, any use of SMR/ESMR services requires the public safety agency to obtain the equipment and issue the equipment to appropriate personnel, as well as train the personnel on the use of the subscriber units and the system. Currently, these systems do not meet the public safety requirements for priority access, survivability, and direct unit-to-unit operation.

6.2 Operational Policies and Procedures

6.2.1 Operational Control

Current policies place few restrictions on the use of interoperability channels. For instance, the frequency 155.475 MHZ is set aside nationwide for "...use in police emergency communications networks operated under statewide law enforcement emergency communications plans'" (47 CFR 90.19[d] and [e][14]). The contents of the statewide plan are not described nor is there an approval process established for the plans. The State of California has established the following guidelines for use of this channel, as well as certain other channels set aside within California for mutual aid purposes. However, it should be noted that these policies are applicable only to California.

Priority 1: Disaster and extreme emergency operations for mutual aid and interagency communications.

Priority 2: Emergency or urgent operations involving imminent danger to the safety of life or property.

Priority 3: Special event control activities, generally of a pre-planned nature, and generally involving joint participation of two or more agencies.

Priority 3a: Drills, tests and exercises.

Priority 4: Single agency secondary communications

This system of priorities has served well to encourage agencies to implement some of the mutual aid channels and to use them while preserving their use for higher order events.

6.2.2 Operational Security Factors

Unauthorized use/access to mutual aid/interoperable channels is a significant concern.

6.2.3 Interoperability Implementation Limitations

There are some issues and/or limitations that are common to all types of interoperability, whether infrastructure dependent or independent.

One issue is a limitation of the number of channels that individual users are able to handle. Originally, this issue was a technological issue that related to the number of channels for which a radio could be "programmed". When crystals were the primary means for selecting the radio frequency, physical limitations and other considerations limited the number of channels (frequencies) available in the radio, which was typically a maximum of four. Thus, users were forced to be very selective of the frequencies that were available in their radios. Oftentimes, the need for "routine" communications prevented inclusion of any frequencies that would provide interoperability with other agencies. Today, as synthesized radios are available with a capability to operate on more than 230 channels[6], the problem is no longer technological, but one of human interface. As the technological problems are solved, the human factors become more important, as most users are unable to remember the specific channels assigned for interoperability and scrolling through the list becomes very time consuming and impractical in an emergency. There have been several recent incidents in which users operating field units have complained about the inability to communicate with other "on-scene" agencies, only to later discover that they unknowingly had a common channel available in their radios. This problem is sometimes further compounded with a lack of commonly used designators to identify the channels among different agencies.

Another problem is a general lack of channels available for interoperability. Whether the reason has been insufficient planning or a critical need to utilize all available channels to satisfy routine operational demands, few channels have been designated or available to satisfy interoperability requirements.

There is a command and control issue that varies to some degree across the different jurisdictions and agencies, but is basically similar. Many commanders are willing to have personnel from other agencies join "their home" system, but somewhat hesitant to allow the personnel within their own agency to join the radio system of another agency when it jeopardizes the commander's ability to maintain communications with his own personnel. A user in the field who cannot be contacted is not available for assignment.

6.3 Spectrum Use and Considerations

Interoperability is hindered by the diversity of the spectrum now used by public safety agencies. Non-federal users are scattered across seven frequency bands[7], while the federal agencies primarily operate their land mobile radio systems in the 162-174 MHz and 406.1-420 MHz bands, as well as the 138-144 MHz band which is primarily used by the Department of Defense. It is currently not possible to provide a radio that will operate across all these bands, at an affordable cost. Thus, the implementation of full interoperability is dependent upon the involved agencies finding some common frequency band in which both are willing/able to operate.

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6 The California Department of Forestry and Fire Protection's Chief Officer radios currently have 320 channels.

7 Non-federal (public safety agencies) operate in the 30-50 MHz, 150-162 MHz, 220-222 MHz, limited use in 420-430 MHz, 450-512 MHz and two bands in 806-824/851-869 MHz portion of the spectrum.

6.4 Regulatory Issues

6.4.1 Federal vs Non-federal Use of Spectrum

Under current policies, practices and procedures, federal agencies request and coordinate the allocation of spectrum through the National Telecommunications and Information Administration (NTIA). Non-federal agencies request the allocation of spectrum from the Federal Communications Commission through one of several designated frequency coordinators. This separation of responsibility for the allocation of spectrum has resulted in some roadblocks to the shared use of spectrum by federal and non-federal agencies engaged in joint operations. The FCC requires that all non-federal agencies desiring to use "federal" spectrum obtain a license to use that spectrum. The process requires that the non-federal agency obtain concurrence and perhaps "sponsorship" from an appropriate federal agency and submit a copy of that concurrence together with their license application to the FCC. The FCC then takes that request to NTIA for concurrence. Assuming concurrence exists, the FCC then grants a license to operate on the "federal" channel. This process must be repeated every five years as the license comes due for renewal. Some federal agencies, however, are reluctant to grant concurrence for a non-federal user to be licensed on one of their channels. They may well want the non-federal user to operate on their channel for interoperability purposes, however, they do not want that non-federal user to be "licensed". Thus, there is a dichotomy between the FCC's demand that all non-federal users obtain a license through them to use federal spectrum and the federal users refusal to allow that process to occur.

Similarly, federal users are hindered in their ability to operate on non-federal spectrum. There is no formal mechanism for this to occur. As a result, non-federal agencies have entered into agreements with federal agencies to grant a "letter license" for the federal agency to operate on non-federal spectrum. These "letter licenses" amount to being a statement from the originator that his/her agency is appropriately licensed on one or more frequencies and that for specified purposes , the federal agency may operate on those frequencies. During such operations, the originating agency accepts full responsibility for proper use of the channel.

The regulations need to provide for equal access by both Federal and non-federal agencies for purposes of interoperability. It may be desirable to restrict this access to certain specified channels, in which case, channels should be designated in each of the frequency bands.

6.4.2 Shared Systems

The use of shared systems in the public safety community has been hindered by the current licensing process. Under the current process, a license to operate on certain frequencies is granted to the person/agency named on the license. That person or agency then becomes the "licensee" in the eyes of the FCC with certain "rights" to the continued use of that frequency or frequencies. Even though licensees must renew their license at certain specified intervals (currently five years for land mobile licenses) very few renewals are denied and

then only upon a showing of cause. Similar "rights" are not granted to the unnamed persons/agencies who may have contributed to the construction of the system and most likely are paying a portion of the operating cost. This affords the named licensee a certain amount of power over the unnamed users. There are numerous examples of the licensee deciding to change operation of the system without consulting the user agencies, perhaps requiring the user agency to replace all the mobile/portable equipment to maintain compatibility with the "new" system. There have also been incidents wherein the licensee decides that the system is no longer capable of providing service to the other users and telling them to find services elsewhere. The notice to vacate may provide for as little as thirty days lead-time to react. This lack of control over one's destiny is unacceptable to many public safety agencies.

The regulations also need to provide for equal access by both federal and non-federal agencies for the purpose of sharing systems. An incentive for agencies to enter into such shared systems would be to give favorable licensing treatment to these systems.

7.0 Future Interoperability Needs

The future interoperability needs are discussed in detail in Section 12.3, *Working Group #3 Report*.

7.1 Summary of Requirements

7.1.1 Direct Unit to Unit Interoperability

The most critical interoperability requirement is for direct unit-to-unit communications, which requires a common mode of transmission.

7.1.2 Additional Channels in Existing Bands

Working Group #3 identified the need for 51 repeatered voice links and 83 simplex voice links within current bands, plus 2 independent high speed data and 2 independent full motion video links. The distribution of the channels within the existing bands is reflected in Appendix A.

It is believed that existing designated interoperability frequencies can be used for 17.5 of the repeatered and 28 of the simplex voice links. The high speed data and full motion video links must be provided within new spectrum.

7.1.3 Additional Channels in Interoperability Band

Working Group #3 identified the channel requirements for existing bands plus a new interoperability band, if selected. A total need for 21 repeatered voice links and 20 simplex voice links within current bands has been identified. The distribution of the channels within the existing bands and the new interoperability channel is reflected in Appendix A.

It is believed that existing designated interoperability frequencies can be used for 13.5 of the repeatered and 13 of the simplex voice links. 31 repeatered voice, 70 simplex voice, 2 independent high speed data and 2 independent full motion video links must be provided in the new Public Safety Spectrum.

7.2 Operational Policies and Procedures

Although the operational policies and procedures are important concerns that should be addressed, there was insufficient time and/or information available to the ISC to properly evaluate the effects of all the issues.

7.2.1 Operational Control

Operational control of systems and spectrum identified as interoperable channels is an important issue, however, there was insufficient time to properly evaluate the alternatives and provide a valid opinion at this time. The ISC recommends that these issues be addressed as the national and regional planning is accomplished.

7.2.2 Operational Security Factors

As more emphasis is put on sharing systems and infrastructures, the capability for additional users and access points will be provided. As more users are provided access to infrastructure, the system security and protection from unauthorized access must be addressed.

Different factors may require evaluation with the introduction of data capabilities over a wireless media. Unauthorized use/access may have new meaning in a data environment.

7.2.3 Liability Concerns

There was some concerns expressed concerning the possible liability of licensees [system owners] to maintain operational reliability in a shared environment, as well as funding responsibilities. There was insufficient time and information available to properly address this issue in the ISC. It is recommended that this issue be addressed at the Steering Committee level as appropriate options are decided and possible mandates and/or incentives are introduced.

7.2.4 National/State/Regional Planning

A national frequency plan and regional frequency plans (as applicable) must be developed and mandated. These plans must include voice (simplex, mobile relay and trunked), data and video.

Standard nomenclatures and identifiers for channels/talk groups must be mandated by the FCC and NTIA for use on all equipment, to include approved identifiers to be displayed for interoperability channels/talk groups on equipment with varying numbers of characters in the channel/talk group display window.

A National Calling Channel and one or more Tactical Channels must be established in **EACH** of the public safety frequency bands. Use of these channels should be similar to that currently designated in the NPSPAC plan (47 CFR 90.16 and §90.34).

As with other mutual aid frequencies, it is important to consider placement within each band. There have been significant problems when mutual aid channels have been placed side-by-side or next to other statewide or nationwide assignments due to adjacent channel interference which can render such channels unusable when operating within close proximity to each other.

7.3 Spectrum Use and Considerations

While the ISC recognizes that the responsibility to identify the spectrum to support the interoperability channels identified is the responsibility of the Spectrum Requirements Subcommittee, some considerations should be addressed.

The ISC recommends that a new Public Safety Interoperability Band be established. Depending on the band selected, this solution could provide some immediate dividends, possibly within two years or sooner, for the public safety community. If at least some of the required channels were provided from existing UHF bands, the benefits could be realized immediately. If the new interoperability band is provided from spectrum that must be vacated by other users, the benefits will not be realized for some time.

7.4 Regulatory Issues

7.4.1 Shared Spectrum/Systems

Shared systems (i.e., large trunked systems which provide service to many governmental entities in a specific geographic area) offer a high level of built-in interoperability. They also offer greater spectrum efficiency than many smaller non-trunked systems or systems trunked on fewer channels. However, shared systems face difficulties which hinder their adoption. Probably the most significant difficulty of shared systems is that they require individual agencies to surrender some autonomy in return for the efficiencies and better coverage of the larger system.

The FCC could implement policies which facilitated the adoption of shared systems. For example, the FCC could require a showing (or statement) on license applications that no shared system can meet the agency's needs, similar to the procedures required by the NTIA for the federal agencies. The FCC could also implement policies which help preserve the autonomy of individual agencies and hence lower the threshold for adoption. For example, the FCC could adopt a policy that said that all communications involving safety-of-life were to be carried at equal priorities. Thus, a tenant on a shared system would not need to fear that the landlord would get superior access to channels in a crunch time.

7.4.2 Commercial Services

The role of commercial services in public safety is yet to be determined, however, discussions in the ISC identified some shortcomings of commercial systems ability to meet public safety needs, based on experiences with current systems. The FCC could adopt policies that would remove some such shortcomings. One such policy, which would reduce problems with access to commercial systems during times of peak usage, would be rules that provide for priority access to commercial systems by public safety users.

Regulatory and eligibility issues are being addressed at the national level by the National Security Telecommunications Advisory Committee (NSTAC). In partnership with NSTAC, the Office of the Manager, National Communications Commissions System, is seeking the FCC's approval to establish Cellular Priority Access Service (CPAS). CPAS will offer non-preemptive priority queuing cellular service to the nation's emergency responders who have national security or emergency preparedness functions.

To invoke CPAS, users must have a bona fide National Security or Emergency Preparedness purpose. Their telecommunications are used to maintain a state of readiness or to respond to and manage any event or crisis which causes or could cause injury or harm to the population, damage to or loss of property, or degrades or threatens the National Security Emergency Preparedness of the United States. The proposal urges the creation of a centralized administration within one Federal Government office, to ensure uniform application of eligibility, procedures and rules and to provide a single point of contact for information and problem resolution.

CPAS defines 5 priority levels and supports the activities of both the private and public sectors. A petition for rulemaking was filed with the FCC by the National Communications System on October 19, 1995, recommending that CPAS be a voluntary service offered by the nation's wireless service providers.

Although the most users agree that the recommendations of the CPAS do not go far enough to satisfy the public safety needs, it may be a vehicle to further state the needs of the public safety community.

However, many of the shortcomings identified flow from market forces and are not readily susceptible to regulatory cures.

7.4.3 Mandates

Although the issue of mandates and incentives are considered to be very important if direct unit-to-unit interoperability is achieved at the level that most desire. For a reduction of the number of individual bands used by public safety to be realized, some kind of incentives and/or mandates will likely be required.

7.4.4 Standards

During the deliberations of the ISC, a number of discussions ensued concerning the development of standards. A minimum baseline technology for interoperability was identified and unanimously approved by the ISC. This baseline technology is discussed in Section 11.2.3.

It was further stated that while the Minimum Baseline for Interoperability presented in Section 11.2.3 will suffice for some time, perhaps as long as 2010, the time will come when most, if not all, users in a given area will be using a digital voice communications platform and will not want to give up the capabilities provided by that platform when switching to analog FM for direct unit-to-unit communications.

Considering the evolution to digital technology, we should not limit future interoperability to an analog baseline. Just as the AMPS cellular standard (which clearly goes far beyond simple analog FM) provides North America-wide cellular interoperability, there is clearly a future need for digital interoperability standards for public safety communications. It is imperative that this baseline be addressed and established within the next two years, to allow the public safety community to develop implementation and migration plans accordingly.

The issue of establishing a group to address digital baseline standards for interoperability became a very controversial subject, and is further discussed in Section 10.5.

7.4.5 International Considerations

As new interoperability channels and spectrum are identified, both cross border interoperability issues, as well as cross border frequency coordination issues must be addressed. As specific spectrum and/or channels are identified by the Spectrum Requirements Subcommittee, international border issues must be addressed.

7.4.6 Recommendations

The FCC and NTIA should establish a task force to identify policies that would facilitate joint use of spectrum by federal and non-federal government users. This task force should also consider policies needed to facilitate the creation of shared systems that support both federal government and non-federal users.

The FCC should consider implementing incentives that facilitate the adoption and use of shared systems for public safety communications.

The FCC should adopt rules that make commercial systems more responsive to public safety needs. Most importantly, the FCC should require commercial systems to offer a priority access option to public safety users.

8.0 O:w of Possible Methodologies

8.1 Direct Unit to Unit

8.1.1 Advantages:

- Ability to work outside of an infrastructure

- Communications in event of infrastructure failure

- Generally limited range often permits high level of frequency reuse

8.1.2 Disadvantages:

- Units must be completely compatible, including common frequencies and mode of operation

- Limited range may be inadequate/adequate coverage for some incidents

Common Access to Infrastructure

8.2.1 Advantages

- Consolidated systems, either conventional or trunked, covering the same geographic area, readily provide interoperability.

- Spectrum efficient. For example, in some states the following three agencies require continuous (24 hr/day) interoperability to provide effective law enforcement and for officer safety; each must be able to independently monitor and transmit to the other two agencies. The first is a state highway patrol agency with primary jurisdiction for enforcing all traffic laws in unincorporated areas of the state and providing traffic investigation assistance to other agencies on request. The second is a county sheriff's department with primary jurisdiction for enforcing all non-traffic laws within the county, for operating the county's prisoner custody system, and for security in the county's courts and jails. Last is a city police department within the same county responsible for general law enforcement within its political boundaries. These three agencies operate in the same RF band using compatible equipment. They can interoperate on each other's systems without the need for any additional spectrum simply by switching to the desired channel or system/talk group of the desired agency. Scanning between channels or systems provides for routine monitoring of the other agency's radio traffic on an ongoing basis.

- Appropriate administrative regulations or functional controls (through hardware or software implementations such as control of mobile relays,

enabling of trunked talkgroup or roamer access, etc), are desirable to prevent misuse of interoperability features

8.2.2 Disadvantages

- Provisions must be made for outside users to enter a system.

- Incoming units must be fully compatible with infrastructure to function, including identical technical requirements for trunked systems.

- Interoperability fails if infrastructure is damaged or otherwise not operational (until such time as infrastructure is restored).

8.3 Interface of Infrastructures

8.3.1 Advantages

- Any two (or more) infrastructures can be bridged together through gateways

- Systems may utilize different frequencies or modes of operation (conventional and/or trunked) provided suitable gateways are used.

- Once an infrastructure-based interoperability solution is in place, it can idle in standby mode and be activated immediately when required, as long as all of the participating systems are operational.

8.3.2 Disadvantages

- Every participating network must have similar geographic coverage to provide assurance of interoperability.

- Networks must generally be in place before an incident which requires their use.

- This method is spectrum inefficient because a separate talk path is required on each system for each simultaneous conversation on the other incompatible system. For example, if the same three agencies described previously in this section have incompatible trunked systems, it would require up to six extra talk paths (2 per system) to interlink infrastructures for day-to-day interoperability, the maximum of six being required when all systems were transmitting (3 simultaneous conversations). In most cases of routine day-to-day interoperability, it is not possible to mix the audio from more than one agency's primary dispatch channel/talkgroup because: (a) field units must know which agency is transmitting, and (b) if an agency is not involved in a mutual response, it does not want traffic related to that response on its primary dispatch link.

- Interoperability fails if any infrastructure becomes damaged or is otherwise not operational (until such time as all infrastructures are restored). The use of deployable infrastructures could mitigate this problem, depending upon the specific incident: it is possible that both communications and transportation infrastructures can be totally destroyed in major disasters (as happened with Hurricane Andrew, Hurricane Iniki, and the Loma Prieta Earthquake); in these cases it can be many hours, even days, before transportable infrastructures can be deployed, whether or not they are immediately available for deployment, because of the roadway destruction. In the three events cited, deployable infrastructure were not operational until 72 hours after the event in the areas with the most damage.

- For digital systems, voice intercommunications between infrastructures using incompatible digital vocoders will probably introduce additional transmission delay and reduce voice quality if it is necessary to translate the signal back to analog and reconvert it to the other infrastructure(s) vocoder system.

8.4 Separate Emergency Radio

8.4.1 Advantages

- Could operate on a unique interoperability band without modification to installed base of radio equipment.

- Could be small and low cost due to optimization to specific interoperability requirements

8.4.2 Disadvantages

- Requires each user needing interoperability to purchase, carry and maintain a second radio or to have a separate radio available for deployment..

8.5 Commercial Services

8.5.1 Advantages

- Wide area to Nation-wide coverage is possible using existing cellular, paging or satellite systems.

- Does not require modifications to current installed base of public safety radio equipment.

- Leverages significant commercial investment of infrastructure

8.5.2 Disadvantages

- Concern of lack of access or priority to system during disasters

- Concern of poor reliability

- Concern of delay in access time

- Concern of lack of security

- Concern of coverage due to terrestrial limitations

- Concern of cost of using commercial services

- Requires users needing interoperability to carry and maintain a second radio

8.6 Multi-band and/or Wide-Band Radios

8.6.1 Advantages

- Bridges a communications link between non-contiguous operating bands.

8.6.2 Disadvantages

- May not be commercially viable within the PSWAC time frame of 2010.

- May have significant size, weight, cost and battery life penalties.

- Probably not be able to span the range of operating frequencies listed in section 12.3.2.1

8.7 Scanners

8.7.1 Advantages

- Currently used for many day-to-day interoperability missions.

- Does not require modifications to current public safety radio equipment deployed.

8.7.2 Disadvantages

- Requires the user needing to interoperate to purchase, carry and maintain two radios.

- Susceptible to interference because of low technical specifications and need for wideband operation.

8.8 Move All Public Safety to a New Band

8.8.1 Advantages

- Seamless interoperability possible with an industry supported baseline technology.

8.8.2 Disadvantages

- Requires the replacement of all public safety installed radio equipment.

- May require going beyond the PSWAC time period of 2010 to significantly improve interoperability.

- Requires significant funding to implement.

- May not be practical to reallocate enough contiguous spectrum from other licensees to accommodate public safety needs in one band.

9.0 Cost/Benefit Analysis

There was insufficient information available to Working Group #7 to provide sufficient time to provide a cost and benefit analysis for the interoperability solutions identified in this report. If feasible, the working group will provide a supplemental report which will be included in this section.

The basic conclusion of the ISC was that as interoperability became more complex, they also became more costly in terms of monetary value.

9.1 Introduction

9.1.1 Background

(This subsection will briefly introduce the cost/benefit analysis and the efforts of Working Group #7)

9.1.2 Interoperability Requirements

(This section will briefly restate the interoperability requirements or missions developed in Sections 5.0, 6.0 and, especially, 7.0)

9.1.3 Methods for Achieving Interoperability

(This subsection will briefly describe the alternative ways or methodologies for achieving enhanced levels of interoperability in each missions. It will draw on the materials from Section 7.0 (especially 7.1) and from various White Papers, including those submitted by Ericsson and Motorola.)

9.1.4 Importance of Cost/Benefit Analysis - General

(This subsection will briefly describe the importance of conducting a cost/benefit analysis in the face of the alternative ways of achieving enhanced levels of interoperability.)

9.1.5 Constraints Associated with the Analysis

(This subsection will describe the constraints placed on the analysis by practical considerations. For example, the alternative of consolidating all public safety communications into a single new band was eliminated from consideration because it was judged that it was unlikely that such a large block of spectrum in a single band could be made available in the time frame of the analysis, the differences in the propagation characteristics of different bands made it unlikely that a single band would be optimum for all agencies (e.g., rural versus urban), and the large investment in legacy systems and the long lead time associated with changing out those systems worked against it. Also, the ISC, for a variety of reasons, chose to recommend 25 kHz/12.5 kHz bandwidth FM as a common mode of communications on channels set aside for interoperability purposes. These reasons included, among other things, previous federal government and Federal Communications Commission actions to migrate to the potentially more efficient channel width, the fact that manufacturers have Intellectual Property Right [IPR] - free access to the technology, the capture effect associated with the FM technology that allows significant frequency reuse, the long history of the technology as an effective communications medium in land mobile applications, and the difficulties associated with selecting another standard given the other challenges faced by the committee and subcommittees.)

9.1.6 Limitations of the Analysis

(This subsection will describe the limitations of the analysis. The limitations stem from the difficulties associated with estimating the benefits and costs in quantifiable/financial terms and from time pressures that, as a practical matter, prevented a full-blown cost/benefit analysis of all the possible alternatives. It will note how the number of alternatives was narrowed based upon the constraints identified in Subsection 8.1.5 and the professional judgement of the participants in the advisory committee and its subcommittees.)

9.2 Benefits of Alternative Ways of Achieving Enhanced Levels of Interoperability

(This section will likely include a number of considerations such as recurring costs of services versus recurring maintenance costs. This section will likely encompass such variables and factors as life cycle costs, experience curves, amortization, economies of scale, etc.)

9.2.1 General Benefits Associated with Enhanced Levels of Interoperability

(This subsection will set the stage for the benefits portion of the analysis by reviewing the generic benefits associated with achieving enhanced levels of interoperability. Examples include the benefits associated with lives saved, property losses averted, additional criminals apprehended, reduced criminal activity because of the increased probability of apprehension, and increased economic efficiency in all types of public safety activities. The latter includes possible reductions in manpower resources due to a reduction in the need for "teaming" across agencies, runners, and the dispatcher time required to repeat messages. It also includes the potential impact on competition in the supply of infrastructure and end user radios and hence on the acquisition and operating costs of such systems and equipment.)

9.2.2 Specific Benefits Associated with Different Interoperability Requirements and Alternatives

9.2.2.1 Additional Background on Interoperability Requirements and Alternatives

(This subsection will provide more information on the requirements for interoperability, but without excessively duplicating the material contained in earlier sections of the ISC report. Alternatives for achieving enhanced levels of interoperability will also be described. Beyond recognition of the two categories of ways to achieve enhanced interoperability — infrastructure dependent and infrastructure independent — all of the alternatives that will ultimately be identified by the subcommittee are not clear at this time. Based on the materials produced so far, however, the alternatives include:

a. Reducing the number of bands used by public safety (with more offsetting increases in the total amount of spectrum allocated to the public safety use)
b. Providing additional spectrum immediately adjacent to the (possibly reduced) number of public safety bands for interoperability purposes
c. Requiring a common mode of communications (25 kHz FM) on the specified interoperability channels

d. Encouraging the deployment of broadband (possibly multimode) radios capable of operating on both the existing and adjacent band
e. Encouraging the deployment shared/consolidated systems (common access to an infrastructure)
f. Providing interfaces/gateways between and among the (possibly reduced number of) independent infrastructures
g. Requiring the limited build-out of some nationwide infrastructure to support interoperability
h. Encouraging the use of commercial systems where appropriate
i. Requiring a planning effort to deal with the use of the interoperability channels

In this subsection, it will be emphasized that the most beneficial method of enhancing interoperability in both the short term and the long term will almost certainly involve a combination of these alternatives. For completeness, the alternatives rejected as a result of the constraints addressed in Subsection 8.1.5 will be explained.

9.2.2.2 Day-to-Day

(In this subsection, the relative benefits associated with each alternative/combination of alternatives will be analyzed and described in terms of the degree to which it enhances interoperability during day-to-day operations.)

9.2.2.3 Mutual Aid

(In this subsection, the relative benefits associated with each alternative/combination of alternatives will be analyzed and described in terms of the degree to which it enhances interoperability during mutual aid operations.)

9.2.2.4 Task Force

(In this subsection, the relative benefits associated with each alternative/combination of alternatives will be analyzed and described in terms of the degree to which it enhances interoperability during task force operations.)

9.3 Economic Costs of Alternative Methods of Achieving Enhanced Levels of Interoperability

9.3.1 Generic Costs Associated with Enhanced Levels of Interoperability

(This subsection will set the stage for the cost portion of the analysis by reviewing the generic costs associated with achieving enhanced levels of

interoperability. Actual estimated costs will not be provided at this point. Rather, the costs will be described in general terms, including the relative complexity of the alternative. The costs will include (a) equipment costs [again, in general terms] associated with the use of multiband or broadband radios as well as (b) other harder to quantify costs such as training costs and the added weight or physical space problems associated with solutions that require the use of multiple radios.)

9.3.2 Specific Costs Associated with Different Interoperability Requirements and Alternates

(This subsection will analyze and describe the costs associated with each alternative/combination of alternatives identified and used in Subsection 8.2. During earlier teleconferences of Working Group #7 and in discussions at the San Diego meeting of PSWAC, there was some disagreement as to how well these costs could/should be quantified. For example, some participants argued that it would be difficult to assign a believable dollar amount to any one approach or group of approaches to enhancing interoperability, while others argued that public safety users [and the Federal Communications Commission] should be given informed estimates of the total costs that such solutions might entail. It is proposed that this be resolved by, first [and as a minimum] evaluating the costs in terms of relative comparisons and known relationships and then attempting to provide at least "order of magnitude", quantified estimates of the costs of the most likely alternatives.)

9.4 Summary of Costs Versus Benefits for the Alternatives Identified

(This subsection will display the results of the Cost/Benefit analysis in graphical or tabular form. It will include a small amount of explanatory text in "bulleted" form. In combination, it will allow a reader to quickly grasp the results obtained.)

10.0 Conclusions

There is no single solution that will solve the inter-agency interoperability problem for the public safety community, due to the unique geographic and regional requirements across the country. There are multiple levels of interoperability solutions which have been outlined and discussed throughout this report. These solutions include both infrastructure dependent and infrastructure independent (direct unit-to-unit) methodologies. Most solutions can be categorized from simple to complex and the optimal solution may use various combinations as the interoperability needs escalate from day-to-day to disaster levels.

10.1 Possible Methodologies

10.1.1 Gateways/Crossband Repeaters

Gateways between two or more system infrastructures can provide viable infrastructure solutions at various degrees of complexity. They can interconnect systems operating in different frequency bands, modes of operation and manufacturer protocols. Most trunked radio systems require predetermined user or "talk" groups to be identified and programmed into the system. As systems become larger and additional user groups are identified, the problem of interconnecting users from other systems or non-trunked users becomes more complex.

Although gateways and cross-band repeaters are not an ideal solution, it is one of the few solutions to achieve interoperability in an infrastructure dependent environment.

Gateways have advantages where they can be set-up and knocked down quickly and where coverage patterns between the systems that the gateway bridges are similar. Gateways are also needed where there is a transfer needed between incompatible systems, protocols, and technologies.

In many cases there is neither time nor opportunity to set up gateways between channels and systems at emergency events. In addition, many users feel that such gateways are chokes rather than outlets, frequently restricting channel effectiveness.

Some of the simplest and least costly forms of gateways and interconnects require the traffic to be broken down to its simplest form (clear analog audio) and requires operator intervention to be accomplished. This type of interconnectivity is the least desirable, but in many cases is the only solution available to the public safety users.

10.1.2 Common Communications Mode for Interoperability

At the very lowest level of use of interoperability channels (one field unit to another - either dependent or independent of infrastructure). There must be a common medium of communications specified for these interoperable channels. Thus, in Section 11.2.3 a minimum Baseline Technology for Interoperability is defined. System configurations and technical offerings vary greatly from one manufacturer to another and most often there is neither time nor opportunity to set up gateways between channels and systems at emergency events. In addition, infrastructure coverage cannot be provided across the entire country and a great reliance must remain on unit-to-unit tactical communications. We must make sure that any radios arriving on an incident have at least a baseline technology capability to talk directly to any other unit on the same frequency band on the scene.

10.1.3 Public Safety Interoperability Band

The concept of establishing a new band exclusively for interoperability is discussed in detail in the White Paper submitted by Ron Haraseth, from the State of Montana. Mr. Haraseth's White Paper is included as Attachment 7.

10.1.3.1 An Operational View

All participants in any joint endeavor must speak the same language to be fully functional. In this case, we must speak the language of emergency response. This fits in with the operational aspects which have been discussed centering around using the Incident Command System (ICS) architecture to identify channels of operation along the same levels of function and command within ICS. ICS attempts to address the problem from an operational stand as opposed to a strictly technical approach.

At the very least, a strictly technical approach is doomed to failure no matter how many channels or gateways are provided if they do not conform to the manner in which they are used. It has often been repeated in the Department of Defense discussions that the military must train as they fight. The same is no less true for public safety responders.

Any incident includes the functions explained by ICS. Identifying functionality using the ICS structure standardizes operations allowing an understanding of the procedures by all involved. By operating under the assumptions in ICS, all parties are aware of their role and responsibilities within the overall event. Designating common names for common functions is the basic precept that makes ICS work. The same situation must take place in the communications structure of any incident. Channels must have designated names and associated usages so that all involved will understand where and in what manner they are to be used.

The basic command level and subsequent lower command levels must have pre-designated (and named) channels associated with those levels. Lower levels can be more flexible and dynamic. Understanding the operational characteristics does not complete the solution, but once they are defined, the correct technical solutions can then be applied.

A technical solution must be practical, relatively inexpensive, ubiquitous, and above all, attainable. A solution must be available both on the near term as well as the long term. It must work with existing systems without causing interference with standard dispatch systems or creating an undue hardship to implement.

10.1.3.2 PI Service Category

The move of the entire public safety operating environment to a single band is not practical, and cross banding existing bands is far less than fully effective. The former being unworkable financially and later being extremely inefficient in terms of spectrum use. However, creating a single common Public Safety Interoperability Service (which is abbreviated as "PI") in one central band is very possible and very practical. This band would be dedicated exclusively for interoperation applications. This will not eliminate the need for dual band radios or two radio installations, but having a universal declared service gives an absolute common technical solution to the common operating requirements of a mutual aid incident. A field tactical vehicle (or hand-held) with the "PI" capability could interact with any other unit similarly equipped. This capability need not be linked in any way to the user's home system operation.

As an example, one unit's basic internal system dispatch operation could be in an 800 trunked environment while another unit could be operating in low band. If these field units' second band or second radio in each case were the common "PI" radio, they would technically be capable of true interoperability. Bringing a third unit into the picture more than clarifies the practicality of a common PI service band.

10.1.3.3 Operational Requirements - Unplanned/Planned Incidents

We can learn much from the communications problems of historical incidents. Those that indicate failures in the communications link may not point directly to solutions. While some failures point to technical deficiencies, many have resulted from operational deficiencies. We also must review the aspects of these incidents that worked correctly and expand on those aspects. Similarly, we must avoid the known points of failure.

Planned incidents fall under the category of preplanned tactical events or locally restricted common action situations that can be anticipated accurately. These events are rarely a problem technically regardless of what systems are involved. By their very nature and description they exist with pre-knowledge and the participants are prepared for the forthcoming actions. Planned incidents are not fully detailed here other than to indicate that they could be handled very easily under the following operational description for unplanned incidents.

By their very nature, unplanned incidents may happen any time and any place. These situations are difficult to plan for in any situation ad even the best and thorough plans can not prepare for all of the possible unknowns.

10.1.3.4 "PI" System Operation

Mutual aid operations that are unplanned are unique and go through several definable phases. The first phase is always the "first response" or "initial attack." Some incidents may never escalate beyond this point. As a typical example, a public safety responder of any service traveling outside of their home coverage area often may be the first contact at a typical accident. Their conventional home dispatch system may be totally unusable. Under the PI scenario, a call on the PI radio to a monitoring station or another mobile in the area may be the one and only response required of the incident.

Other incidents may escalate requiring the same first responder to communicate to more units of various types. As long as the terminology and operating aspects of the PI capable radios are standardized, all units would be compatible. More developed incidents requiring the declaration of a planned operation under ICS would see the command shifted from the first responder to a more appropriate Incident Commander (IC). From this point on, any units entering the operation and conforming to the PI radio standard would be automatically capable of inclusion into the ICS command structure. Local units working as strike teams or individual resources lower in the ICS structure could use their own internal radio system for their level of operation or if mixed with dissimilar units, they could use assigned PI channels. In either case, communicating up the ICS chain of command would occur on the PI radio channel assigned for that purpose.

It is generally accepted that isolating a unique incident from routine daily radio traffic is to be preferred. A unique PI service would easily allow such an action.

Again this scenario is dependent upon standardized common assigned names associated with standardized associated channels used under standard operating procedures. This requirement, although it may seem extreme, is absolutely required for any successful multi-disciplinary incident. All aspects of a successful incident (not just radio operation), require the same standard procedure.

It is important for full universal utilization that a national standardized plan be devised and tied very closely to operating restrictions and requirements, This should be a basic requirement of any interoperability solution.

10.1.3.5 The PI Solution

The above descriptions include the following basic requirements:

* Find a relatively free band of frequencies, preferably central to existing public safety bands.

* Define specific frequencies and pairs of frequencies using developed ICS guidelines.

* Freely license these frequencies to all eligible public safety/service providers under operational as well as technical regulations.

* Restrict use to mutual aid interoperation.

The preceding requirements may seem somewhat simplistic, however there is a flexibility to the operational aspects of the PI solution that could allow for much higher levels of robust capabilities. **This would be a fresh and new service which could be implemented without regard to any backward compatibility requirements.** It need not be tied to existing technology and modulation schemes. This leads to a plethora of possibilities:

* Narrow channel bandwidth (or equivalent) should be specified for maximum spectrum efficiency.

* Digital modulation could be required for the same reason.

* Digital modulation leads to the fact that data transfer would be a natural possibility.

* Bandwidth on demand applications (or the equivalent) could also be implemented for the very same reason.

* Encryption could also be very easily adapted considering the possible digital nature of the service. Over the air rekeying (OTAR) should be a requirement.

* Although conventional mode infrastructure independent operation is basic and mandatory to support first response capabilities, trunking should be encouraged for escalated incidents. Trunking would have several advantages for implementation of escalated incidents or for systems embedded in local or regional systems. Caches could be developed that include base/controller equipment that would allow dynamic over the air reconfiguration of all units involved in the incident. This could be enhanced by requiring every radio manufactured to have an internal unique ID similar to the NAM in cellular radios. The ID should be easily read by units entering the incident either by physical connection, optical, or wireless. While such advanced types of operations would require knowledgeable and available communications unit leaders, this activity already takes place on large ICS incidents with existing programmable equipment.

Migration to this interoperability solution could take place as soon as rules and regulations were put into place. There are of course stumbling blocks such as adopting standards for a new operation, but these could also be looked upon as building stones. This solution would not require scrapping any existing system or worry about compatibility with existing systems and the associated costs.

10.1.4 Separate Emergency Radios

Separate radios are currently used by many agencies to achieve direct unit-to-unit interoperability, when the user agencies operate on disparate frequency bands.

This solution could lend to the Separate Interoperability Channel, which could actually reduce the number of radios required by some agencies by having a single common band for interoperability.

This is not the ultimate solution to interoperability, because it still requires a separate radio to achieve interoperability.

10.2 Alternatives For Improving Interoperability

As desirable as the *Long Term Solutions* recommended in Section 11.2 are for ultimately providing a greater level of interoperability between and among public safety and public service agencies, they do not improve interoperability in the shorter term. This is true for two reasons, even if the concept of a separate interoperability band is implemented:

First, in addition to the VHF and UHF bands, public safety and public service entities have large investments in the 800 MHz band and, to a lesser extent, at low band. Moreover, during the PSWAC process certain users have expressed the opinion that both of these bands have very desirable characteristics in certain applications. For example, public safety agencies in some rural areas have indicated that low band VHF is particularly effective in providing outdoor coverage over vast distances and in rough terrain. Similarly, other public safety agencies have noted that systems operating in the 800 MHz band are particularly effective in urban areas where in-building coverage is crucial to accomplishing their missions. Because of the large investment in systems operating in the 800 MHz band and the desirable propaga-

tion characteristics of that frequency range, it is apparent that many agencies will continue to operate in the band for the foreseeable future. Because it is not economically practical to build broadband radios that will operate in both low band and the proposed interoperability channels at high band, or in both the proposed interoperability channels at UHF band and the 800 MHz band, there is some doubt that the final solution would fully solve the interoperability problems even if the new interoperability channels were made available immediately.

Second, even if all public safety and public service operations could be consolidated in the VHF and UHF bands in the shorter term, the interoperability problem would not be entirely alleviated because it is also not economically practical to build a single broadband radio that will operate over both bands. Thus some agencies may continue to operate and invest in VHF systems because, for example, of their superior coverage in rural areas while others may continue to operate and invest in UHF systems. Thus, the Interoperability Subcommittee concludes that other methods may be necessary to assure complete interoperability even with the reallocation of new interoperability channels near the existing VHF and UHF bands.

Based on this analysis we conclude, as stated above, that, as desirable as the long term solutions recommended are for ultimately providing a greater level of interoperability between and among public safety and public service agencies, they do not improve interoperability in the shorter term.[8] Thus, special efforts are required to achieve greater interoperability in the shorter term pending the adoption and implementation of the longer term solutions and as an insurance policy in the event that the longer term solutions are delayed or precluded for unforeseen reasons.

Encouraging the deployment and utilization of shared/consolidated systems (e.g., statewide, multi-agency, multi-discipline networks) in public safety and public service applications can improve interoperability in the shorter term because it does not depend on the reallocating and clearing of spectrum designated for interoperability purposes. It improves interoperability for the obvious reason that, properly designed, any end user unit (or dispatcher) can communicate with any other end user or group of end users. Providing common access to a single infrastructure can solve many, if not all of the problems associated with day-to-day interoperability among the agencies involved. It can also make substantial contributions to meeting the mutual aid and task force requirements for interoperability. Encouraging the deployment and utilization of shared/consolidated systems has other significant advantages as well. When implemented using modern trunked radio techniques, such systems can improve spectrum efficiency and/or improve the level of service (e.g., reduced waiting time), provide a host of advanced features and functions based on software capabilities, and capture potential economies of scale and scope for the agencies involved.

Providing gateways/interfaces between and among independent public safety infrastructures can also improve interoperability in the shorter term because it does not depend

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[8] It should be noted that for similar reasons, agreement on a common mode of transmission (e.g., a common air interface) on existing operational channels alone would not solve the interoperability problem in the shorter term.

on reallocating and clearing of spectrum specifically designated for interoperability purposes nor does it depend on the adoption of a common mode of transmission for all of the independent systems.[9] It improves interoperability for the obvious reason that, properly designed and implemented, any end user (or dispatcher) can communicate with any other end user via the gateway. Gateways also have the advantage that they can accommodate systems operating in different frequency bands and employing different types and vintages of equipment. In particular, they can accommodate systems employing different modes of transmission, thus facilitating competition in the provision of the independent systems. It should be stressed that gateways/interfaces can add to system delay and poorer response times, and this must be factored into the system interface requirements.

Encouraging the use of commercial wireless systems, where operationally appropriate and where adequate coverage exists today, can also improve interoperability in the shorter term because it does not depend on reallocating and clearing of spectrum designated for interoperability purposes. The increased use of public, commercial systems has been controversial in the ISC and in the other subcommittees of PSWAC as well. It is beyond the scope of this Section to review that controversy, but it is clear that a commercial wireless system designed to serve the public at large and interconnected with public voice and data networks can provide improved interoperability at least in some cases. Indeed, public commercial networks are designed by their very nature to offer anyone-to-anyone service. The usefulness of commercial wireless systems in improving interoperability can be further enhanced by providing gateways between public safety systems and commercial infrastructures. Such gateways would (a) facilitate the use of commercial systems where appropriate in routine public safety operations, (b) improve access by the public to public safety agencies and, (c) facilitate the use of commercial wireless systems as backup to public safety systems in emergency situations.

As noted in the table below, promoting or requiring the build-out of some nationwide infrastructure to support interoperability is not a shorter term solution to the interoperability problem if it is interpreted to mean the deployment of a system operating on the new interoperability channels. However, promoting the development and deployment of gateways to facilitate interoperability between and among public safety agencies and between public safety agencies and commercial wireless service providers could, for the reasons stated above, improve interoperability and, at the same time, produce significant other benefits as well.

Also, as noted in the table, requiring a planning effort to deal with the use of the reallocated interoperability channels does not represent a shorter term solution because the interoperability channels are not yet available. However, planning aimed at encouraging and facilitating the shorter term improvements described in this Subsection may be useful.

It should be apparent from the analysis contained in the paragraphs immediately above that there are a number of alternatives for improving interoperability in the shorter term. Moreover, these alternatives (encouraging the deployment and utilization of shared

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[9] Gateways/interfaces do create additional demand for spectrum to replace channels utilized for interoperability which, once again, points to the importance of obtaining spectrum relief expeditiously.